Is there an Economic Case for Energy-Efficient Dwellings in the UK Private Rental Market?

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Abstract

The rented sector of the housing market is a key concern for policies trying to improve dwelling-level energy efficiency levels. Currently, stepping up energy efficiency levels in the residential sector is hindered by a number of uncertainties. For rental properties, this is complicated by the split incentive problem (i.e. landlords do not benefit directly from the savings arising from these investments). Instead, the benefits are enjoyed by the tenants of these upgraded properties via lower energy bills and/or enhanced thermal comfort. Hence, the only way to recoup the investments is typically for landlords to obtain higher rents. This study confirms that energy efficiency features, as measured by the Energy Performance Certificate rating, are positively associated with a small but significant influence on transaction prices and quoted rental prices. Conversely, there appears to be a price discount for dwellings in the lowest energy performance category. A model of time-on-market yields inconclusive results but there is some, albeit weak, evidence of a negative relationship between time-on-market and energy efficiency ratings as more energy efficient dwellings tend to lease up more quickly.

Keywords: Energy efficiency; Green property; Hedonic model; Private rental market; Split incentives; Sustainability

1. Introduction

The present study focusses on a crucial sector of the housing market, the Private Rented Sector (PRS), which has experienced high growth rates in recent years and now provides housing to some five million households in the UK (Paragon, 2015). Apart from its size and importance, the PRS also presents an economic dilemma not typically observed in the owner-occupied segment. This dilemma which is effectively a barrier to achieving higher energy efficiency is known as the split incentive problem and arises because capital investments in energy efficiency are made by one party, the landlord, but the benefits are reaped by another, the tenant, as the latter enjoy lower utility bills and enhanced thermal comfort. Hence, the only economic channel for recouping the initial capital outlay is the landlord's ability to charge a higher rent. Whether higher rents are indeed achievable for properties with higher energy efficiency is therefore a crucial question which landlords and property investors need to consider before committing to an investment (Adan and Fuerst, 2015).

Closely related to the question of an energy efficiency rent premium is the question of transaction prices. Price signals are a key feature of markets. When information about important characteristics of a good is unavailable or expensive to obtain, price signals may be used to indicate quality and attractiveness. Real estate buyers need to determine and screen out low-quality assets from high-quality ones despite not being able to directly and fully observe the quality characteristics. With regard to the energy efficiency performance of a building, potential sellers are often unable to directly verify intrinsic green attributes of a property and must rely on incoming information from the marketplace in the form of eco-labels.

To improve the information available to those in the PRS in EU countries, an Energy Performance Certificate (EPC) must be provided by the landlord to the tenant before a property can be let out or sold. Overall, the current situation is marked by uncertainties that impede further progress towards greening of the UK housing stock. For landlords, uncertainty persists over key parameters, such as the payback period and market acceptance of rent increases. For tenants, energy efficiency ratings and/or even energy bills from previous tenants may only have limited predictive power for their own energy consumption.

The present study first examines a sample of PRS properties in England with a hedonic regression model, dividing a property's price into different components related to its corresponding characteristics, in order to establish if home energy efficiency can lead to increased property sales prices. The results indicate that high EPC ratings in dwellings are generally associated with a price premium and vice versa for low ratings.

In the second part of this paper, rental rates and time-on-market are analysed using the same analytical framework. A rental premium is found for energy efficient properties, even when controlling for a number of rental determinants. These findings suggest that capitalisation of green features into rental and sale prices are likely to accelerate the adoption of energy efficient buildings.

The contribution of the present paper is twofold. It differs from previous studies by being, to the best knowledge of the authors, the first study to present a rigorous economic analysis of the value of energy efficiency in the English private rented sector by combining a rich database previously inaccessible to researchers evidence with public data on amenities and socio-economic population characteristics. The second contribution is more general in that it seeks to explore if a largely unregulated rental market such as the UK yields price and rent capitalisation from EPCs that are comparable to the more regulated markets in mainland Europe. It is not straightforward to formulate an expectation prior to empirical testing. On the one hand, more regulated markets tend to provide more clarity to landlords and tenants on legally allowable rent increases following a green retrofit which may help gains in energy efficiency to manifest themselves in rents and prices more easily. On the other hand, where these more regulated markets also grant considerable subsidies and tax deducations for making homes more energy efficient, landlords may not seek to recoup their expenses via the rent channel to the same extent as their peers in non-regulated markets. Hence, the level of capitalisation would be expected to be lower in a relatively unregulated market. Following this introduction, the paper is divided into five sections. Section two discusses relevant previous studies. Section three details the hedonic pricing model. Section four explores the datasets and descriptive statistics. Section five provides a discussion on the regression outputs. Section six concludes and suggests extensions for future research.

2. State of research

Studies of barriers to achieving greater energy efficiency in the existing building stock typically focus on either technical or non-technical barriers (Femenías et al., 2018). A comprehensive discussion of technical barriers can be found in O'Malley and Sorrell (2003). Non-technical obstacles can be divided into four categories: limitations on decision-making, rational behaviour, organisational failures, and market failures - e.g. imperfect information and split incentives (Sorrell, 2003).

The present study is closely related to the non-technical obstacles branch of literature, by empirically exploring market failures in the PRS in England through property prices. An important problem explored in this paper is related to split incentives as a consequence of the information asymmetry problem. Information asymmetries between homeowners and tenants negatively impact the adoption of building energy efficiency measures, consisting of an effective barrier to increase green property investments (Jaffe and Stavins, 1994; Femenías et al., 2018).

Very few studies have attempted to quantify the price effect of energy efficiency levels in the residential market, let alone the PRS. Below is a short review of the main existing empirical evidence.

2.1. Energy efficiency and sales prices

Despite the fact that there is a wide variability on the scale of price effects on energy efficiency, the empirical results provided by the present paper are broadly consistent with most of the studies in the literature, in which positive relationships between property prices and energy efficiency are reported. However, few studies find divergent results, concluding that either energy performance is not necessarily rewarded (Cerin et al., 2014) or even energy efficiency being negativey related to property price (Yoshida and Sugiura, 2010).

Berry et al. (2008) conducted one of the first studies on the effect of mandatory green certification on residential house prices. The study reports a significant relationship between the energy efficiency rating of a dwelling and its sale price in Australia between 2005 and 2006, with premiums of 1.23% found in 2005 and 1.91% in 2006, in response to a 0.5 score increase on the 0-10 energy rating scale.

In the European Union, Brounen and Kok (2011) examined the impact of energy labels on house prices in the Netherlands. Residential properties with an above-average green label rated A, B and C command premiums of 10%, 5.5% and 2.2% respectively. In a parallel study in Ireland, Hyland et al. (2013) show that there is an 9.3% price premium for A-rated dwellings, 5.5% premium for B ratings, and a significant -10.6% discount for F and G ratings. A small but positive relationship between energy performance and sale prices is also found for the housing market in Northern Ireland (Davis et al., 2015).

Studies conducted in the UK draw a similar conclusion. Fuerst et al. (2015), using 325,950 dwellings sold at least twice from 1995 to 2011, report significant positive premiums for dwellings rated A/B (5%) or C (1.8%). For dwellings rated E (-0.7%) and F (-0.9%), significant discounts are found. Recent studies in Nordic countries - Denmark (Jensen et al., 2016) and Finland (Fuerst et al., 2016), confirm a significant role of energy efficiency ratings for sale prices.

The consensus of a green premium in the housing market is not unanimous among all studies. An important theoretical economic argument underpinning the lack of a premium would be that landlords are already charging the maximum obtainable rent. This argument has its antecedents in Ricaridian rent theory and has been reformulated by Samuelson (1959). When housing markets are inelastic, this entails that housing supply is fixed. In this situation, landlords would charge the maximum rent they can obtain from tenants based on the latter's wages, which reflect the marginal product of their labour. Therefore, any improvements in energy efficiency may remain unrewarded if tenants already pay the maximum share of their incomes. For example, the two empirical studies below find a negligible impact on prices.

Using Swedish housing transactions between 2009 and 2010, Cerin et al. (2014) show that energy performance is not rewarded across all property-price classes and ages of residential properties and conclude that there is little evidence of price penalties for the least energy efficient properties, although, within the most energy efficient houses, a significant association between energy performance and house prices is reported. Similarly, Yoshida and Sugiura (2010) show a significant price discount of 5.5% and a lower depreciation rate for newly constructed green condominiums in Tokyo. Interestingly, this suggests that properties with high energy efficiency ratings are likely to command lower market prices.

Appendix A provides an overview of empirical studies examining the impact of energy efficiency on house prices, in which there is a slight trend towards smaller green premiums in recent studies.

2.2. Energy efficiency and rents

Empirical studies examining the capitalisation of energy efficiency in the PRS are rare. The apparent gap in the literature is not surprising. Quality concerns and suitability of available data are often cited limitations and there is no clear consensus on the scale of the price effect of energy efficiency. Case studies from Sweden, Germany, and Ireland all report a positive relationship between energy efficiency and residential rents.

Zalejska-Jonsson (2014) shows a premium of 5% of total rent in green buildings in Sweden.

Similarly, Hyland et al. (2013) report that A-rated properties have a green sale price premium of 11% and a green rent premium of 1.9% in the Irish residential market. Interestingly, not only does this study suggest a positive relationship between energy efficiency and rental and sale prices, but it also suggests that buyers exhibit a stronger willingness to pay more for energy efficiency than tenants.

Cajias and Piazolo (2013) find a rent premium of 1.7% in the German market. In related research, Kholodilin et al. (2017) found that energy efficiency are generally capitalised into rental prices in Berlin. Earlier, Rehdanz (2007) arrived at similar conclusions exploring the German housing market.

3. Research design

The hedonic pricing model is the standard methodology for examining value determinants in housing. In the present study, this method is used to primarily isolate the effect of EPC rating on price, taking the following fully linear form (Rosen, 1974):

$$\boldsymbol{P}_{it} = \beta_{0t} + \sum_{k=1}^{K} \beta_{kt} \boldsymbol{X}_{ikt} + e_{it} \tag{1}$$

where $\boldsymbol{P}_{it}$ is the transaction price of property i, measured as the natural logarithm of the price in GBP per square metre (m^2) at time t, in which $t = 0 \ldots T$, and $\boldsymbol{X}_{ikt}$ is a vector of K explanatory locational and physical characteristics, including categorical variables related to energy labelling and property characteristics. Note that the present analysis uses the sale price per square metre rather than the total recorded price. This reduces the predictive power of the model but provides a more robust measure of prices as it eliminates the size effect contained in the recorded transaction price. The term β_{0t} refers to the intercept, β_{kt} is a vector of characteristics parameters to be estimated, and e_{it} is a random error term (white noise) with mean zero, capturing additional factors impacting house prices. The hedonic weights assigned to each variable are equivalent to their overall contribution to price. The estimation of rents adopts the following functional form:

$$\begin{aligned}\log R_{it} = \beta_0 + \beta_1 \sum_{k=1}^{K} Physical\ characteristics_{it} \\ + \beta_2 \sum_{k=1}^{K} Locational\ characteristics_{it} \\ + \beta_3 \sum_{k=1}^{K} Neighborhood\ profile_{it} + \beta_4 \sum_{k=1}^{K} EPC\ rating_{\ it} + \epsilon_{it}\end{aligned} \tag{2}$$

The dependent variable $\log R_{it}$ is the natural logarithm of the asking rent per m^2 in GBP, indexed by property i and time t. The logarithmic-linear model specification is the preferred functional form due to the fact that it mitigates the effect of extreme values and it facilitates the interpretation of the coefficient as average percentage premiums/discounts.

Previous emprical studies on rental determination provide no conclusive list of variables to be included in the model. In order to isolate the effect of the environmental certificate on rent, the focus is on housing units' physical characteristics as well as neighbourhood characteristics. The term β_{kt} is a vector of parameters that captures the marginal effect each attribute (X_{ikt}) of the rental unit has on the rental rate:

$$\partial X_{ikt} / \partial R_{it} = \beta_{kt} \tag{3}$$

ϵ_{it} is a random composite error term, assumed to be independent across observations and normally distributed, with mean zero and constant variance σ^2. The independent variable of interest is the vector of energy effiency ratings, which controls for the property energy performance rating. Hedonic estimates can be biased due to the omitted-variable bias (OVB) problem. While every effort has been made to include all relevant value drivers in the current analysis, further details on limitations of hedonic pricing models can be found in Balk et al. (2013).

4. Data and descriptive statistics

The hedonic analysis outlined above requires a large sample of property transaction prices and characteristics. For the purpose of the present study, data from several sources were merged.

4.1. Dataset building

In the first step, data on market prices were obtained from the UK's Land Registry, comprising residential transaction prices from 1995 to 2013. In the second step, through address matching, this data was cross-referenced with the HomeCo Internet Property Ltd rental data to obtain information on property size, dwelling type, age, and energy performance.

The sample was further enhanced by adding socio-economic data from the Office for National Statistics and indicators provided by the UK Census. Particularly the English Index of Multiple Deprivation (IMD), which contains an aggregation of the following seven neighbourhood profile domains: income; employment; education, skills and training; health and disability; crime; barriers to housing and services; and living environment. All reported to be important locational control variables in previous studies. Our model specifications included either the combined IMD score or its constituent elements but it was found that this choice does not significantly alter the results with regard to the variables of interest.

To ensure a representative sample, observations across hundreds of different neighbourhoods in England were obtained via a stratified random draw. The sample covers approximately 4,600 rental observations, which includes information on sale prices of virtually all of these properties. It is worth noting that the analysis was performed on a smaller number of observations (4,132 and 4,076 observations for sale prices and rental values respectively) due to missing values in their respective explanatory variables.

Fig. 1 compares the sample distribution with the population distribution of all EPCs reported by the Department for Communities and Local Government and the English Housing Survey. Despite minor differences, the data distributions can be considered sufficiently comparable.

Additionally, the hedonic regression model should control for smaller variations between the sample and the underlying population.

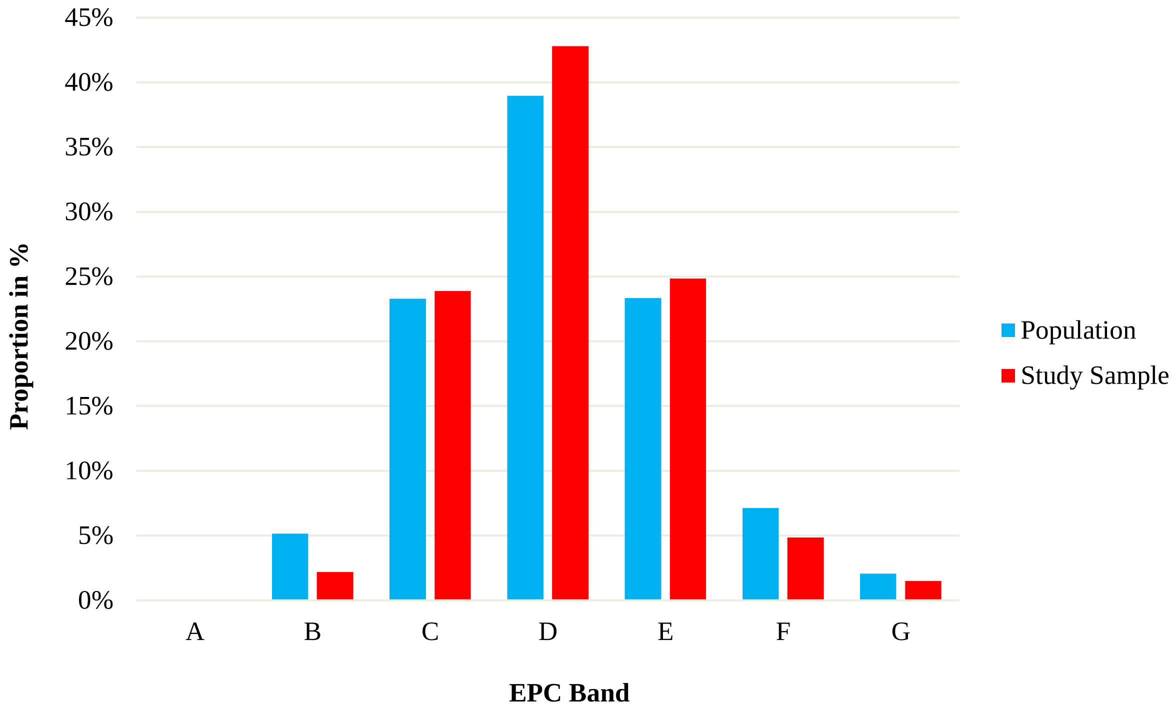

Fig. 1. Distribution of EPC bands for study sample (red) and external reference, DCLG (blue). Data sources: Landmark and DCLG.

A further concern is that important price determinants may be highly correlated with EPCs. **Fig. 2** confirms that the distribution of EPC bands varies considerably depending on the year of construction. Hence, it was necessary to include age of construction (vintage bands) in our model to disentangle these two effects. However, there may be other confounding effects that remain uncontrolled for even when building age is included in the model. For example, it is to be suspected that F and G rated properties could generally be in worse condition and have lower aesthetic appeal, inflating the price discount to buildings with low EPC ratings. Since there is no information on the condition of a property in the present study, it cannot be ruled out that these price drivers enter the calculated EPC price effects.

Similarly, it is possible that F and G rated properties are perceived to entail higher costs in the longer run, not only due to their substandard energy efficiency levels and higher energy bills but also in terms of general maintenance work. The equilibrium sales price would then adjust downwards to reflect the present value of these higher deferred costs.

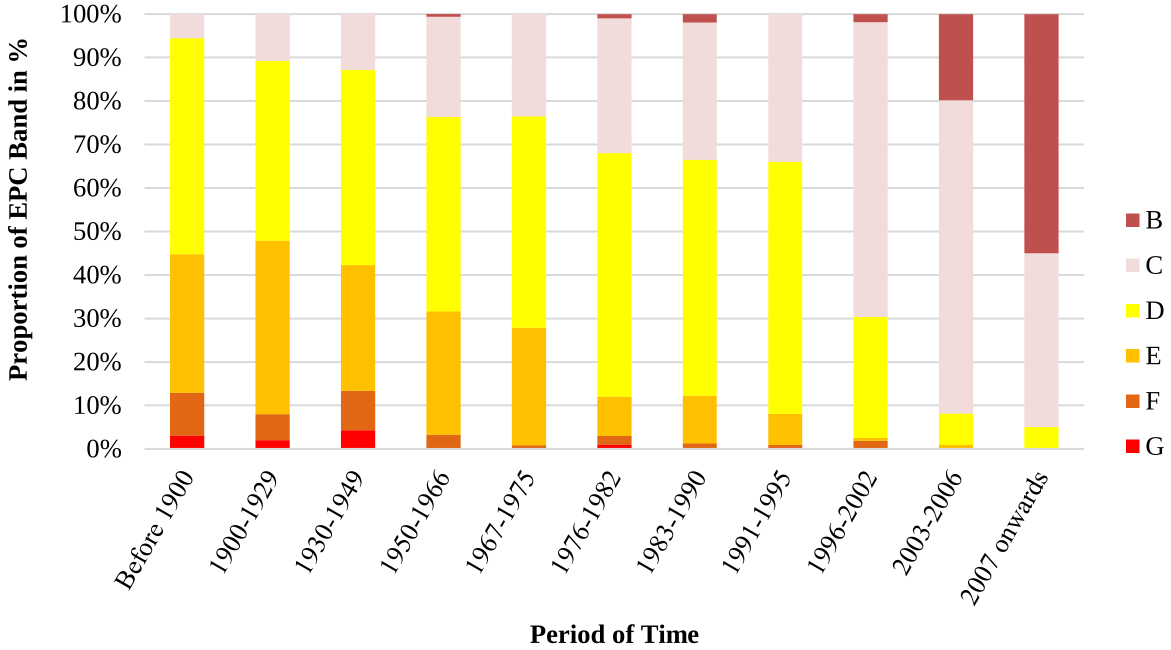

Fig. 2. Sample distribution by EPC band and vintage period. Data source: Landmark.

Information on rents and dwelling characteristics was also obtained from HomeCo. Efforts were made to ensure that each dwelling included in the sample had both an on-market and an off-market date. According to the data providers, this increased the likelihood of the asking rents in the sample matching the transacted rents.

This sample contains rental prices of 5,300 properties advertised for rent from 2011 to 2015, along with corresponding information on property location, type, size, number of bedrooms, and vintage class. Socio-economic information from the census and the IMD were added, along with information on energy performance ratings obtained from the EPC register.

4.2. Regression diagnostic and robustness checks

A series of diagnostic and robustness checks were undertaken. As some flats and terrace houses are held on a leasehold basis, tenure was added as an additional control variable in the regression. Moreover, only properties which changed hands more than once were included in the sample to minimise measurement error and missing information.

The Variance Inflation Factor (VIF) was also applied to test for multicollinearity. Overall, the estimation of the EPC price effects appears to be robust to these variations and tests, but it is important to bear in mind that the magnitude of these effects may still be distorted by correlated factors that were not included in the model.

4.3. Key features of the dataset

The descriptive statistics in Appendix B show interesting points. Average prices in the PRS in England seem to be lower than the overall housing market, which is consistent with evidence published by the Bank of England (Bracke et al., 2015). Also, in line with statistics from the English Housing Survey, the transacted buy-to-let properties are relatively smaller in size.

Almost half of the properties were constructed before 1950, with less than 6% built in the last decade. Terraced properties and flats account for approximately 54% and 10% of the sample, respectively. Most properties are also held in freehold. In contrast to leasehold, freehold tenure refers to a case in which the ownership of a building or plot of land is outright for an unlimited period of time. Overall, the properties appear to be spread evenly across the different deprivation levels.

Moreover, approximately two-thirds of the dwellings have EPCs rating below C, with none being rated A and only 2% being rated B. Similarly, only 1.5% are in the G category. As low numbers in these categories may produce unreliable results, a combined B/C category and a combined F/G category are formed. In line with previous studies, EPC ratings exhibit a strong correlation with building age.

The average monthly rental rates in England exhibit marked persistent differences as shown in **Fig. 3**, with listed rental prices in the South being priced significantly higher in comparison with the North.

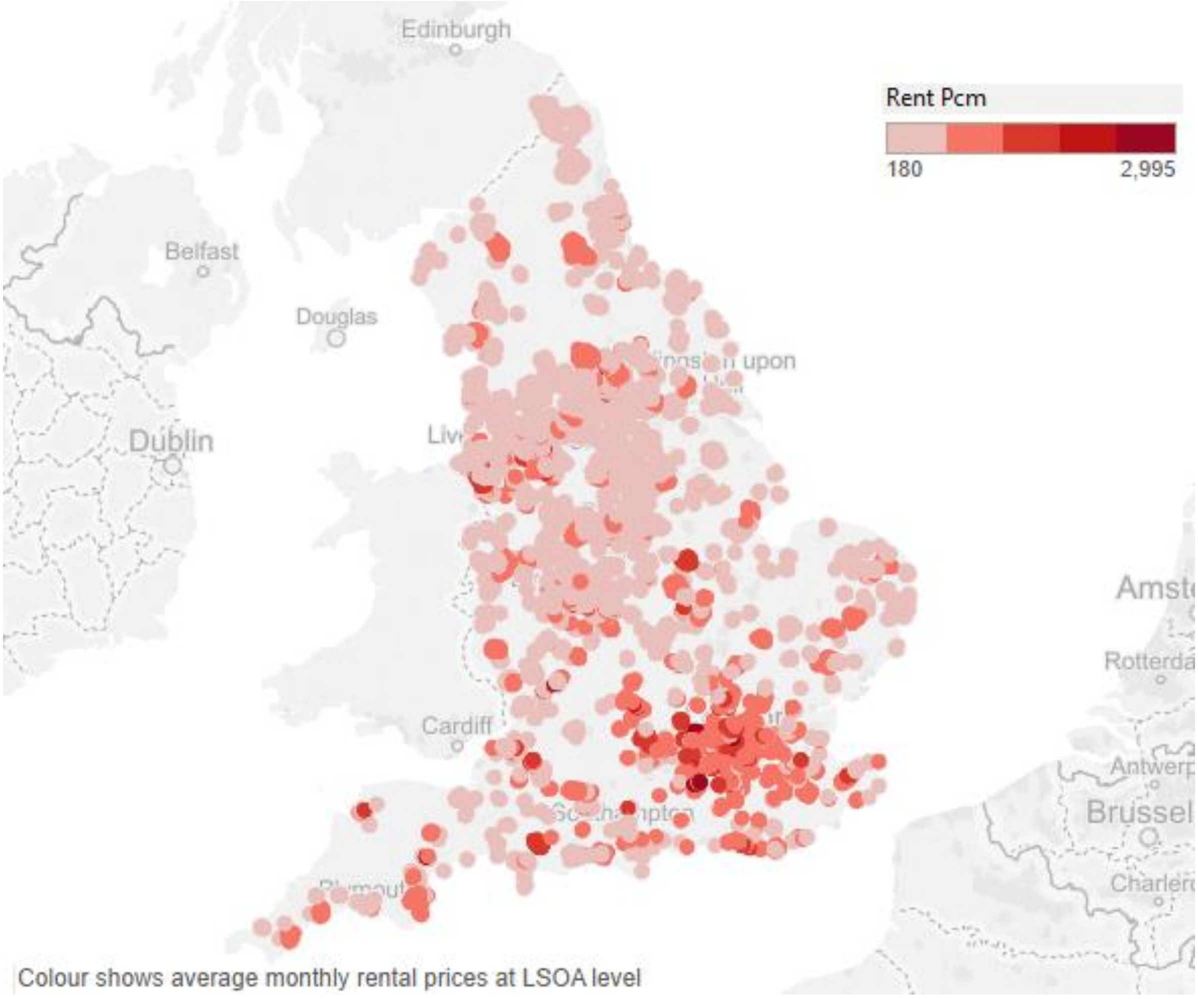

Fig. 3. Average monthly rental prices. Each dot represents an LSOA in England with lighter colours indicating lower rents and vice-versa.

In terms of marketing periods, **Fig. 4** illustrates that, on average, they are higher in the North and relatively low in the Southeast and London. These differences in rental rates and marketing periods between the North and South of England is historically linked to differences in economic activity. These descriptive statistics are consistent with a priori expectations derived from market statistics.

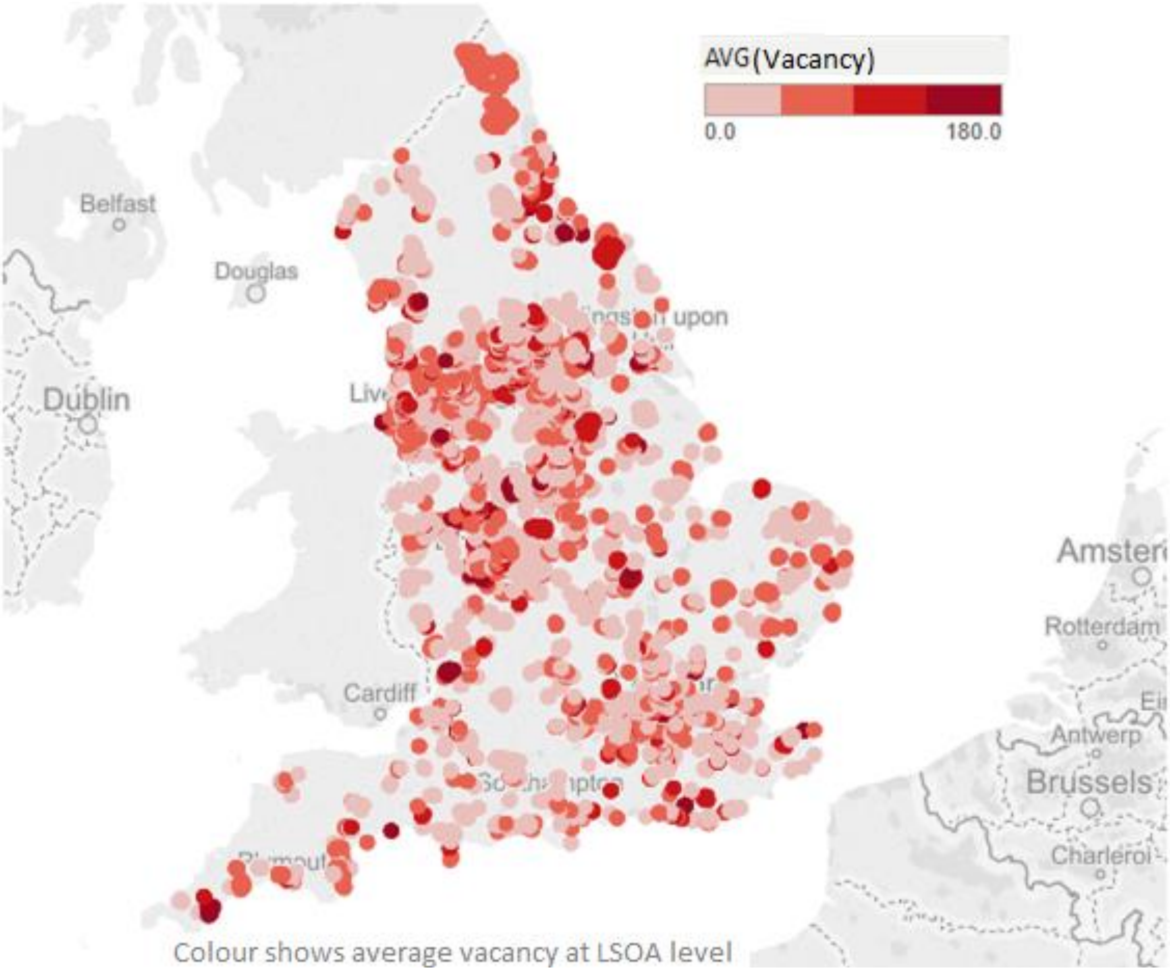

Fig. 4. Average time-on-market (difference between listing date and off-market date) at the LSOA level in England. Each dot represents an LSOA in England with lighter colours indicating shorter time on market and vice-versa.

Appendices D and E provide descriptive statistics of the categorical variables. The sample largely consists of flats and terraced houses and over 60% of the properties contain two bedrooms. The majority of the properties in the sample (86%) are located in urban settlements. This is consistent with the spread of private rented properties in England.

In terms of socio-economic area characteristics, properties are spread evenly across the different levels of deprivation. The geographic spread of the observations in the sample is also statistically desirable, in which approximately 21% of the properties are located in the Northwest, 20% in Yorkshire, 14% in West Midlands, and 8% in the Greater London.

In line with the national average, 34% of the properties in the sample are in the D-rated category. There is, however, a clear shortage of A-rated properties (only 1 observation) and G-rated properties (less than 1% of the sample). In this study, for practical reasons, the sole A-rated property in the sample is excluded and F and G rated properties are clustered together.

5. Results and discussion

The estimation results for the hedonic regression on log sale prices are shown in **Table 1.** The model fit as indicated by the R-squared captures between 43% and 44% of the variation in sale prices. This is in line with expectations since price per square metre rather than total price paid is used as the dependent variable.

Turning to the variable of interest, there is broadly a statistically significant relationship between the energy performance rating and the sale price of a dwelling. Relative to band D, which is the most frequently reported EPC band and is thus used as the baseline category, the pattern of price effects reveals a significant and positive effect of approximately 6% for B/C rated dwellings. For properties in the F/G category, depending on the specification, there is a statistically significant discount of 10-11% compared to D-rated properties. No significant relationship is found for E-rated properties. Model 2 is an alternative estimation using robust regression to account for influential observations that may exert leverage on sensitive coefficient estimates.

When the price per square metre is regressed against energy efficiency score and a vector of control variables (Model 3), a one percent increase in the 0-100 energy efficiency score produces an approximately 0.12% increase in the predicted dwelling price.

Table 1
Energy rating and sale price: hedonic estimations.

Dependent variable: log sale price per m^2	Model 1 OLS (bands)	Model 2 Robust regression	Model 3 OLS (continuous)
Log EPC			**0.119*** **
EPC band = D vs.:	**Reference**	**Reference**	
EPC band B/C	**0.061*** **	**0.063*** **	
EPC band E	**0.004**	**0.001**	

EPC band F/G	**-0.101***	**-0.112****	
Number of bedrooms	0.119***	0.118***	0.118***
Log floor area in m^2	-0.587***	-0.573***	-0.573***
Tenure freehold = yes	0.194***	0.187***	0.191***
Rural area = yes	0.000	0.014	0.015
Purchased brand new	-0.033	-0.038	-0.037
Log multiple IMD score	Components	0.038***	0.038***
Constant	8.964***	9.615***	9.141***
Vintage era fixed effects	Yes	Yes	Yes
Property type fixed effects	Yes	Yes	Yes
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.44*	*0.43*	*0.43*
Sample Size	*4,132*	*4,132*	*4,132*

The asterisks show significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used. Complete results are shown in Appendix C.

Next, rental rates are analysed to ascertain if the pricing relationships found in sales transactions also hold for the private rental market. The estimates in **Table 2** provide a detailed description of rental prices as a function of their determinants. Each model explains a relatively large proportion of the variation in rent price. Depending on the specification, the number of bedrooms coefficient suggests that one additional bedroom increases the monthly rental price by approximately 10-11%. The negative but significant relationship between rental price and floor area reflects that the rental price per m^2 for the larger properties is likely to be relatively slightly lower than that of much smaller properties. Furthermore, there is a significant rental price premium of 5-7% associated with rental units located in urban areas.

Turning to the price effects of EPC ratings, B-rated units are found to command a green rent premium of approximately 4% compared to the reference EPC band D. In addition, rental units with EPC band C show a similar rent premium, between 3% and 5% of rent. Conversely, F/G-rated units present a rent discount of approximately 5% in the robust estimation but this coefficient is not significant in the baseline OLS estimation.

Given the large degree of heterogeneity in the rental stock, a closer investigation by property type seems warranted. Allen et al. (1995) argue that hedonic price functions may not be identical across property types since the structural parameters determining rent levels of flats (apartments) are likely to be different for other property types. Drawing on this insight, interaction terms involving property types and the natural logarithm of EPC rating were added to the regression in order to investigate this assumption. In Model 3, semi-detached, terraced house, and flats have a positive statistically significant relationship with log EPC in comparison with the reference category (i.e. detached vs. log EPC).

Moreover, as detailed in **Appendix F**, neighbourhood factors our found to be relevant determinants of rent levels, consistent with previous studies (Kain and Quigley, 1970; DiPasquale and Wheaton, 1992; Potepan, 1996).

Table 2
Energy rating and rental price: hedonic estimations.

Dependent variable: log of monthly rent per m^2	Model 1 OLS	Model 2 Robust regression	Model 3 OLS with interaction terms
Log EPC			**-0.159**
EPC band = D vs.:	**Reference**	**Reference**	
EPC band B	**0.038***	**0.026**	
EPC band C	**0.049*****	**0.030*****	
EPC band E	**-0.001**	**0.001**	
EPC band F/G	**-0.035**	**-0.049****	
Interaction Terms (Property Type vs. Log EPC)			
Detached vs. Log EPC			Reference
Semi-detached vs. Log EPC			0.237**
Terraced House vs. Log EPC			0.239**
Flat vs. Log EPC			0.247**
Number of bedrooms	0.112***	0.096***	0.113***
Log floor area in m^2	-0.705***	-0.745***	-0.703***
Tenure freehold = yes	0.023	0.016	0.014
City or Urban area = yes	0.068***	0.051***	0.061***
Log multiple IMD score	Components	0.022***	0.021***
Constant	4.115***	4.828***	5.247***

Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.63*	*0.52*	*0.62*
Sample Size	*4,076*	*4,076*	*4,076*

Asterisks indicate significance levels: *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used. Complete results are shown in the Appendix F.

Finally, **Table 3** reports the results for time-on-market, defined as the number of days between making a letting advert available on-line and removing it, against the full set of control variables. It is, however, apparent that the explanatory power of the models is generally low and that most of the coefficients are not statistically significant. This is not surprising as several important determinants of the time on market such as individual over or underpricing and the number of competing rental units listed for rent at any given time are not represented in the estimation equation.

Table 3
Energy rating and time-on-market: hedonic estimations.

Dependent variable: log of time-on-market in days	Model 1 OLS	Model 2 Robust regression	Model 3 OLS with interaction terms
Log EPC		**-0.129**	**-0.481**
EPC band = F/G vs.:	**Reference**		
EPC band B	**-0.345***		
EPC band C	**-0.230**		
EPC band D	**-0.065**		
EPC band E	**-0.283***		
Interaction Terms (Property Type vs. Log EPC)			
Detached vs. Log EPC			Reference
Semi-detached vs. Log EPC			0.308
Terraced House vs. Log EPC			0.626
Flat vs. Log EPC			0.366
Log Monthly Rent	-0.173*	-0.035	-0.185*
Number of bedrooms	0.050	0.026	0.052
Log floor area in m2	0.073	0.055	0.076
Tenure freehold = yes	-0.033	0.013	-0.024
City or Urban area = yes	-0.105	-0.146**	-0.103
Log multiple IMD score	0.062*	0.003	0.061*
Constant	3.536***	4.024***	5.379**

Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.03*	*0.01*	*0.02*
Sample Size	*4,069*	*4,069*	*4,069*

Asterisks indicate significance levels: *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used. Complete results are shown in the Appendix G.

Previous studies also report that, although the physical characteristics of a rental unit are important drivers, time-on-market also varies systematically with factors such as tenant mobility (Guasch and Marshall, 1985). This implies that additional determinants of the marketing period are unaccounted for in the estimation of the coefficients. Despite being inconclusive, two interesting observations emerge from these results.

Firstly, the negative coefficient of rent level indicates that rental units with relatively higher listed rental prices are likely to stay listed for longer, with the caveat that the equilibrium rent level is assumed to be set exogenously, but landlords can deviate from this equilibrium by setting too high or too low asking rents, which would in turn affect time-on-market. Secondly, in Model 1, B and E-rated rental units are predicted to achieve a relevant statistically significant lower time-on-market in comparison to those in the lowest EPC category of F/G. The remaining coefficients of energy efficiency bands and the energy efficiency score are not statistically significant.

5.1. Research findings connection with previous comparable studies

The positive price premiums reported in the present study for dwellings with favourable energy efficiency ratings are consistent with the hedonic buy-to-let analysis of Fuerst et al. (2016) in Wales and particularly the significant premiums found for the overall housing market in England (Fuerst et al., 2015). However, a diverging result compared to the Wales study is our finding of a significant price discount for F and G rated buy-to-let properties. Consequently, the present paper’s results for England do not appear to support the conclusion of the previous Wales study, in which PRS buyers do not price-discriminate against low-rated properties to the same extent as owner occupiers due to the split incentive problem. While it would be necessary to directly compare a matched sample of owner-occupied *versus* buy-to-let dwellings in England for a full assessment of this question, the diverging findings for the bottom-rated EPC group may be due to inherent structural differences of the stock and/or time period considered in those studies.

5.2. Implications for theory and practice on sustainability

The importance of property energy reduction relies on the fact that buildings are resposnible for approximattely 40-50% of energy consumption globally as well as 33% of greenhouse gas emissions (Castleton et al., 2010; Berardi et al., 2014). Moreover, improving the housing stock is one of the major targets of the European Union, for example in its Energy Efficiency Directive 2012/27/EU (EED) (Femenías et al., 2018). Overall, the results provided by the present study reveal a statistically significant relationship between energy performance as captured by the EPC and market prices. Therefore, price premiums are reported for buildings with favourable energy efficiency levels and, conversely, price discounts are tied to less efficient energy properties. The importance of such results relies on the fact that it empirically supports the subject perception of economic value added by charging higher rental rates as a compensation of green property investments.

The realisation of economic value-added as a return on green property investment through higher rental rates can a be a relevant incentive to increase such investments, which is highly desirable since public investment on building production made by European countries has been reduced and public funds are scarce. Therefore, the effective implementation of energy saving policies relies more on market forces – such as the ones explored in the present study – than on public financial support (Gruis, 2008; Copiello, 2015; Femenías et al., 2018).

6. Conclusions

A demonstrable link between achievable PRS rents and energy efficiency levels is crucial for landlords to have a monetary incentive for investing in energy efficiency. The results of the empirical analysis confirm that energy efficiency features exert a small but broadly significant influence on both transaction prices and quoted rental prices. A model of time-on-market against similar control variables yields inconclusive results but there is, albeit weak, evidence of a negative relationship between time-on-market and energy efficiency rating.

Future research may aim to further unravel the causal relationship between energy efficiency and prices by analysing changes in observed or perceived energy efficiency features in the same dwelling units over time. Also, as the present analysis could not control for the general state of repair of a rental property, follow-up studies examining physical characteristics such as new kitchens, bathrooms or the general quality of the property are warranted.

Overall, consistent with the extant literature on drivers of ‘green’ investments in the housing market, the results provide further empirical evidence on the relationship between energy efficiency ratings and pricing decisions in the PRS and demonstrate that the features captured by EPCs are broadly significant price and rent determinants.

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Appendices

Appendix A

Table A.1

Overview of selected studies on energy efficiency capitalisation in the housing market.

Study	Methodology	Country	Results
Amecke (2012)	Standard hedonic model	Germany	Energy performance certificates have a limited effect on purchasing decisions
Berry et al., (2008)	Standard hedonic model	Australia	A, B or C rated properties command premiums of 10%, 5.5% and 2.2%
Brounen and Kok. (2011)	Heckman's two-step estimation (FGLS)	Netherlands	Building with a green label sells at a premium of 3.6 %
Cerin et al., (2014)	Standard hedonic model	Sweden	Energy rating, on average, does not contribute to the market price premium of a house
Chen et al., (2014)	Standard hedonic model	Taiwan	Price premium exists for green features but premium for green label is not significant
Davis et al., (2015)	Standard hedonic model	Northern Ireland	A small but positive relationship between energy performance and sale prices
Deng et al., (2012)	Standard hedonic model and fixed effect	Singapore	Substantial economic returns to green buildings in Singapore
Fuerst et al., (2015)	Standard hedonic model	England	14% premium of the highest band of energy ratings
Fuerst et al., (2016)	Standard hedonic model	Wales	18.5% and 4% for A/B rated and C rated buy-to-let properties and no significant discount for lower-rated properties
Hyland et al., (2013)	Standard hedonic model	Ireland	A-rated property receives a price premium of 11%, and B-rated properties increase the price by 5.8%
Högberg (2013)	Standard hedonic model	Sweden	Home buyers consider the information in the EPCs, entailing a price premium
Jensen et al., (2016)	Standard hedonic model	Denmark	Energy performance rating of properties play an important role in relation to sale price
Kahn and Kok (2014)	Standard hedonic model and propensity score matching	USA	Green price premiums of 2-4%
Yoshida and Sugiura (2010)	Standard hedonic model	Japan	Green residential buildings trade at a price discount of 5.5%
Zheng et al., (2012)	Standard hedonic model	China	Significant price premia for 'green' properties in the Chinese housing market

Appendix B

Table B.1.

Descriptive statistics for key variables (n = 2,202).

Continuous variables	**Mean**	**Std. Dev.**
Price (P1)	127,860	258,666
Price (P2)	172,662	358,311
Compound annual growth rate (%)	4.47%	6.70%

Total floor area (m^2)	80	35	
Energy efficiency rating	59	14	
Categorical variables	**Categories**	**Frequency**	**% of total**
Dwelling type	Detached	221	10.04%
	Flat	213	9.67%
	Semi-Detached	583	26.48%
	Terrace House	1,185	53.81%
Tenure	Freehold	1,820	82.65%
	Leasehold	382	17.35%
Vintage class	Missing	275	12.49%
	Before 1900	326	14.80%
	1900–1929	491	22.30%
	1930–1949	187	8.49%
	1950–1966	152	6.90%
	1967–1975	115	5.22%
	1976–1982	100	4.54%
	1983–1990	155	7.04%
	1991–1995	112	5.09%
	1996–2002	158	7.18%
	2003–2006	111	5.04%
	2007 onwards	20	0.91%
Number of bedrooms	Missing	65	2.95%
	0	1	0.05%
	1	143	6.49%
	2	929	42.19%
	3	768	34.88%
	4	225	10.22%
	5	48	2.18%
	5 +	22	1.30%
Energy efficiency band	A	0	0.00%
	B	48	2.18%
	C	526	23.89%
	D	942	42.78%
	E	546	24.85%
	F	107	4.86%
	G	33	1.50%
Urban/ rural	Urban	1,782	80.93%
	Rural	420	19.07%
IMD decile where IMD-1 is the most deprived 10% of LSOA	Missing	116	5.27%
	IMD-1	179	8.13%
	IMD-2	201	9.13%
	IMD-3	195	8.86%
	IMD-4	227	10.31%
	IMD-5	238	10.81%
	IMD-6	221	10.04%

IMD-7	197	8.95%
IMD-8	218	9.90%
IMD-9	212	9.63%
IMD-10	198	8.99%

Appendix C

Table C.1.

Energy rating and sale price: hedonic estimations.
Dependent variable: logarithm of sale price per m².

Variable	Model 1	Model 2	Model 3
Log EPC			0.119***
EPC band = D vs.:	Reference	Reference	
EPC band B/C	0.061***	0.063***	
EPC band E	0.004	0.001	
EPC band F/G	-0.101*	-0.112**	
Property type = Detached vs.:	Reference	Reference	Reference
Semi-detached	-0.181***	-0.197***	-0.188***
Terraced House	-0.346***	-0.367***	-0.355***
Flat	0.007	-0.002	0.011
Number of bedrooms	0.119***	0.118***	0.118***
Log floor area in m^2	-0.587***	-0.573***	-0.573***
Tenure freehold = yes	0.194***	0.187***	0.191***
Rural area = yes	0.000	0.014	0.015
Purchased brand new	-0.033	-0.038	-0.037
Vintage class = Post 2002 vs.:	Reference	Reference	Reference
Missing	-0.177***	-0.179***	-0.185***
Pre 1900	-0.174***	-0.167***	-0.184***
1900-1929	-0.305***	-0.302***	-0.315***
1930-1949	-0.312***	-0.313***	-0.319***
1950-1966	-0.445***	-0.444***	-0.452***
1967-1975	-0.308***	-0.321***	-0.334***
1976-1982	-0.262***	-0.261***	-0.271***
1983-1990	-0.307***	-0.305***	-0.312***
1991-1995	-0.201***	-0.207***	-0.218***
1996-2002	-0.113***	-0.117***	-0.118***
Log multiple IMD score	Components	0.038***	0.038***
Log employment score	0.039***		
Log education score	0.041***		
Log health score	0.024***		
Log income score	0.021**		
Log crime score	0.010		
Log barriers to housing score	-0.005		
Log living environment score	0.012		
Constant	8.964***	9.615***	9.141***

Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.44*	*0.43*	*0.43*
Sample Size	*4,132*	*4,132*	*4,132*

Asterisks indicate significance levels: *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used.

Appendix D: *Distribution charts of dwelling characteristics.*

Fig. D.1. *Sample proportion of vintage classes.*

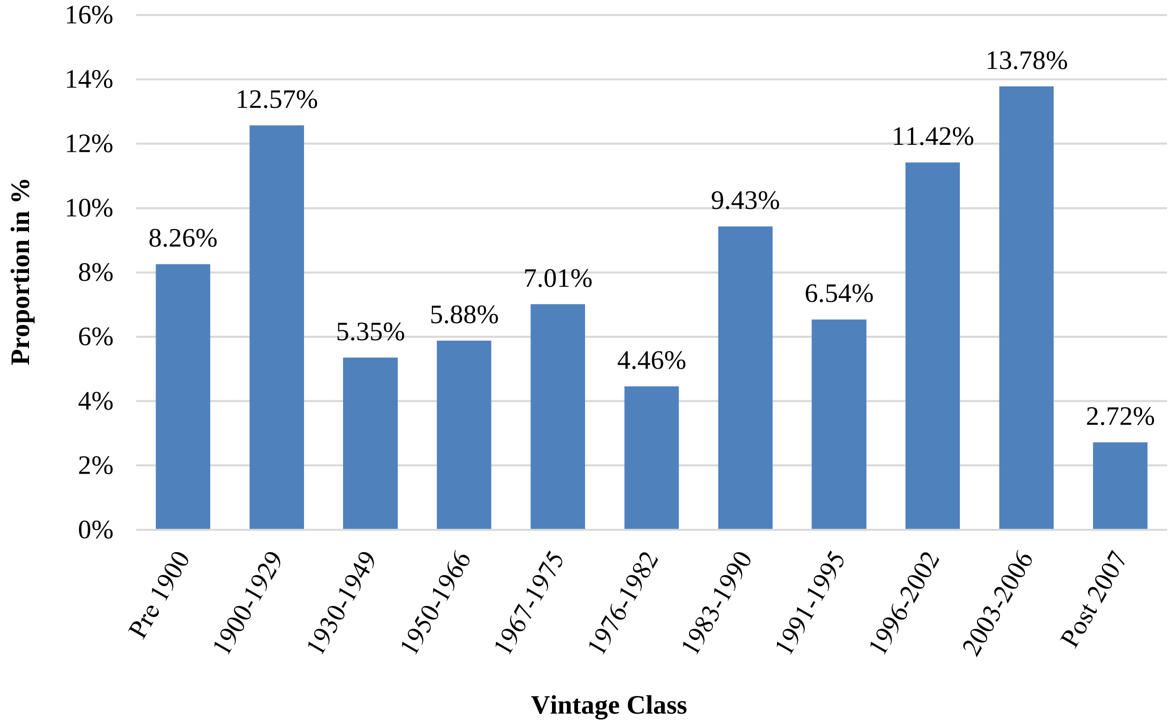


Fig. D.2. *Sample proportion of dwelling types.*

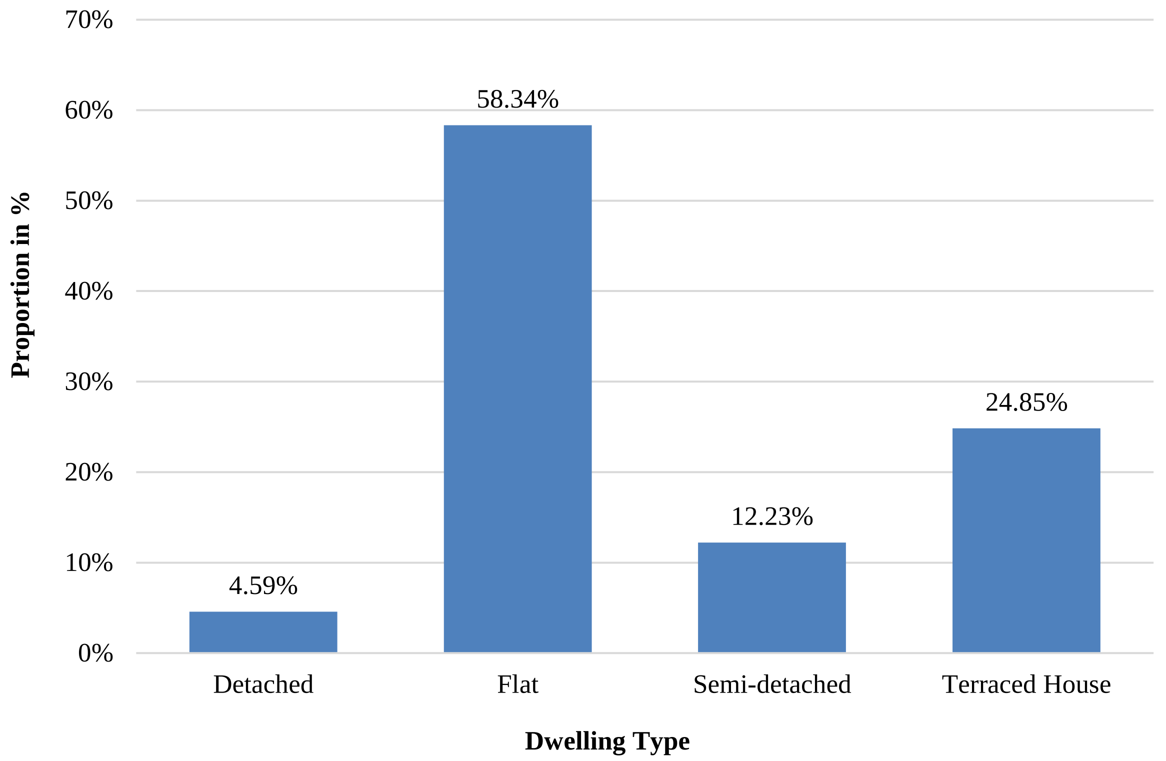


Fig. D.3. *English IMD deciles.*

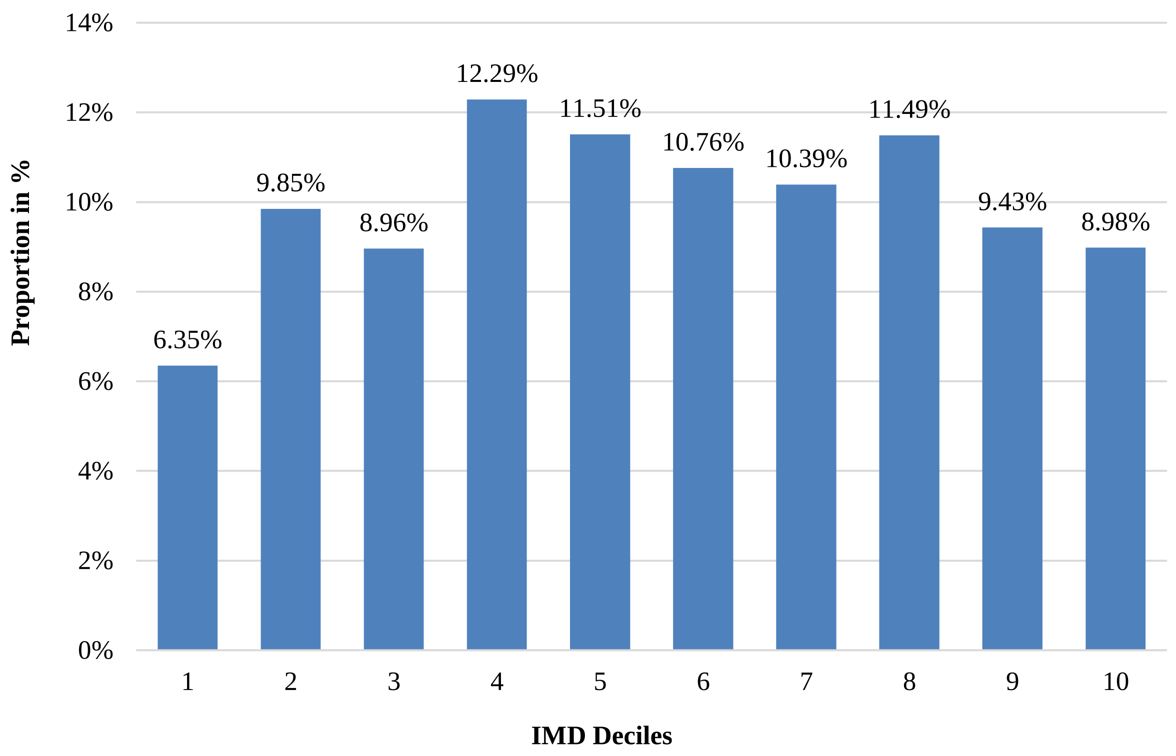
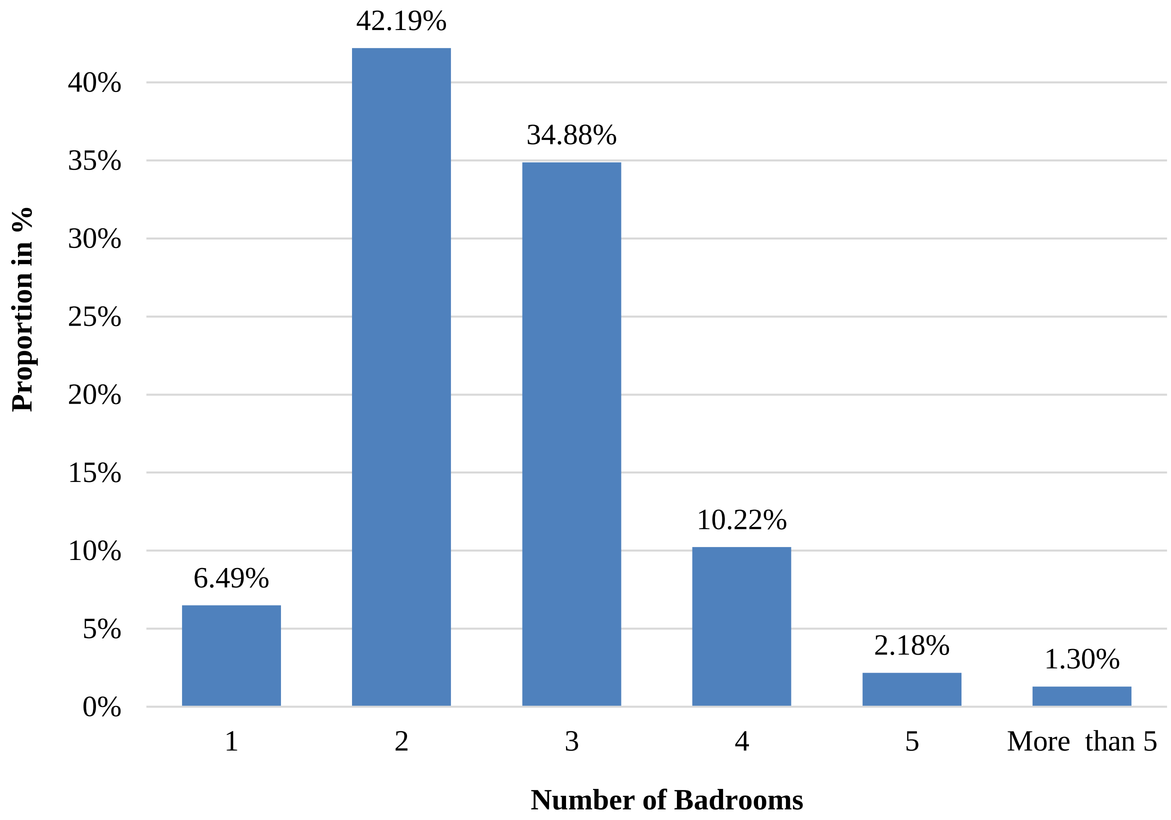


Fig. D.4. *Sample proportion related to the number of bedrooms.*



Appendix E

Table E.1.

Descriptive statistics of the categorical data in the sample (n = 4,702).

Variable	Categories	Frequency	% of total
Dwelling type	Detached	216	4.59
	Flat	2,747	58.34
	Semi detached	576	12.23
	Terraced House	1,170	24.85
Vintage class	Missing	592	12.57
	Pre 1900	389	8.26
	1900-1929	592	12.57
	1930-1949	252	5.35
	1950-1966	277	5.88
	1967-1975	330	7.01
	1976-1982	210	4.46
	1983-1990	444	9.43
	1991-1995	308	6.54
	1996-2002	538	11.42
	2003-2006	649	13.78
	Post 2006	128	2.72
Number of bedrooms	0	1	0.02

	1	723	15.6
	2	2,790	60.21
	3	833	17.98
	4	219	4.73
	5+	69	1.46
EPC rating	A	1	0.02
	B	494	10.49
	C	1,666	35.38
	D	1,596	33.89
	E	739	15.69
	F	173	3.67
	G	40	0.85
IMD decile where 1 is the most deprived 10%	1	271	6.35
	2	420	9.85
	3	382	8.96
	4	524	12.29
	5	491	11.51
	6	459	10.76
	7	443	10.39
	8	490	11.49
	9	402	9.43
	10	383	8.98
Urban/ rural	Urban	4,066	86.35
	Rural	643	13.65
Region	North East	197	4.18
	North West	946	20.09
	Yorkshire	942	20
	East Midlands	522	11.09
	West Midlands	647	13.74
	East of England	301	6.39
	London	385	8.18
	South East	436	9.26
	South West	333	7.07

Appendix F

Table F.1.

Energy rating and rental price: hedonic estimations.
Dependent variable: log of monthly rent per m^2.

Variable	Model 1	Model 2	Model 3
Log EPC			-0.159
EPC band = D vs.:	Reference	Reference	
EPC band B	0.038*	0.026	
EPC band C	0.049***	0.030***	
EPC band E	-0.001	0.001	

EPC band F/G	-0.035	-0.049**	
Property type = Detached vs.:	Reference	Reference	Reference
Semi-detached	-0.091***	-0.090***	-1.063**
Terraced House	-0.142***	-0.157***	-1.125***
Flat	-0.065	-0.157***	-1.082**
Interaction Terms (Property Type vs. Log EPC)			
Detached vs. Log EPC			Reference
Semi-detached vs. Log EPC			0.237**
Terraced House vs. Log EPC			0.239**
Flat vs. Log EPC			0.247**
Number of bedrooms	0.112***	0.096***	0.113***
Log floor area in m^2	-0.705***	-0.745***	-0.703***
Tenure freehold = yes	0.023	0.016	0.014
City or Urban area = yes	0.068***	0.051***	0.061***
Vintage class = Post 1995 vs.:	Reference	Reference	Reference
Missing	0.015	-0.007	0.008
Pre 1900	-0.014	-0.053***	-0.023
1900-1929	0.006	-0.118***	-0.002
1930-1949	-0.046	-0.057***	-0.058**
1950-1966	-0.048	-0.046**	-0.051*
1967-1975	-0.035	-0.062***	-0.053**
1976-1982	-0.038	-0.045**	-0.044*
1983-1990	-0.028	-0.040**	-0.032*
1991-1995	0.006	-0.001	-0.003
Log multiple IMD score	Components	0.022***	0.021***
Log employment score	0.024***		
Log education score	0.023***		
Log health score	0.011**		
Log income score	0.022***		
Log crime score	-0.001		
Log barriers to housing score	-0.009		
Log living environment score	0.020***		
Constant	4.115***	4.828***	5.247***
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.63*	*0.52*	*0.62*
Sample Size	*4,076*	*4,076*	*4,076*

Asterisks indicate significance levels: *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used.

Appendix G

Table G.1.

Energy rating and time-on-market: hedonic estimations.
Dependent variable: log of time-on-market in days.

Variable	Model 1	Model 2	Model 3
Log EPC		-0.129	-0.481

EPC band = F/G vs.:	Reference		
EPC band B	-0.345*		
EPC band C	-0.230		
EPC band D	-0.065		
EPC band E	-0.283*		
Property type = Detached vs.:	Reference	Reference	Reference
Semi-detached	0.212	0.168	-1.070
Terraced House	0.251	0.209*	-2.322
Flat	0.209	0.189	-1.307
Interaction Terms (Property Type vs. Log EPC)			
Detached vs. Log EPC			Reference
Semi-detached vs. Log EPC			0.308
Terraced House vs. Log EPC			0.626
Flat vs. Log EPC			0.366
Log Monthly Rent	-0.173*	-0.035	-0.185*
Number of bedrooms	0.050	0.026	0.052
Log floor area in m2	0.073	0.055	0.076
Tenure freehold = yes	-0.033	0.013	-0.024
City or Urban area = yes	-0.105	-0.146**	-0.103
Vintage class = Post 1995 vs.:	Reference	Reference	Reference
Missing	0.028	0.026	0.065
Pre 1900	-0.171	-0.173*	-0.094
1900-1929	-0.200	-0.083	-0.154
1930-1949	-0.283*	-0.189*	-0.227
1950-1966	0.170	0.145	0.212
1967-1975	-0.268*	-0.046	-0.209
1976-1982	-0.225	-0.088	-0.174
1983-1990	0.029	0.041	0.083
1991-1995	-0.109	0.014	-0.045
Log multiple IMD score	0.062*	0.003	0.061*
Constant	3.536***	4.024***	5.379**
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
R-squared (model fit)	*0.03*	*0.01*	*0.02*
Sample Size	*4,069*	*4,069*	*4,069*

Asterisks indicate significance levels: *p = 0.05, **p = 0.01 and ***p = 0.001. Robust standard errors are used.